Compaction and Drainage

by Michael DePew

This article represents the first of three articles on soil compaction and drainage issues. In this first part, Michael DePew discusses and defines terms that will give the reader a better understanding of soil science principles relating to soil mechanics and soil strength principles.

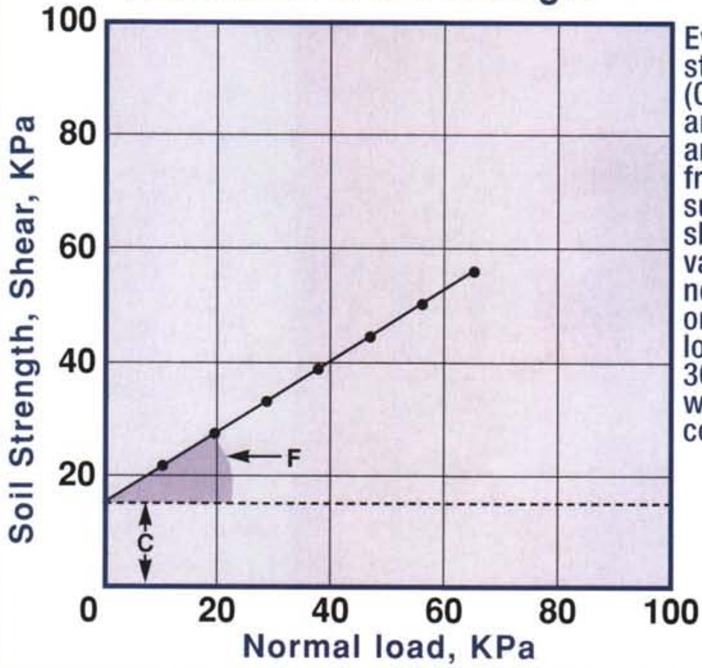
Soil compaction is fundamentally a simple concept. Namely, the solid mass of a bulk soil volume is compressed into a smaller volume of the same mass. This results in an increase of solids and a decrease in void or pore volume. The decrease in total pore volume is normally accompanied by a redistribution of pore size toward finer pores. In general then, compacted soils will exhibit a higher proportion of finer pores that are subject to being water filled. Compacted soils can readily suffer from a lack of adequate aeration porosity.

To understand compaction and the conditions and circumstances that affect compactability, it is important to understand some basic principles of soil mechanics, namely soil consistency and soil strength relationships.

Table 1. **Consistency limits for various soils**

Texture	% Clay	Consistency, mass water content (%)		
		Shrinkage Limit	Plastic Limit	Liquid Limit
sandy loam	15	15	17	21
sandy clay loam	25	18	24	40
clay	50	10	32	59

Figure 1. **Evaluation of soil strength**



Evaluation of strength (C=14 KPa) and friction angle (F=32°) from a measurement of shear at various normal loads on a clay loam soil at 30% mass water content.

Consistency

The physical state of soil—whether it behaves as a solid, plastic, or liquid—is referred to as consistence. Soils in the plastic state have the property of flowing after some threshold stress has been exceeded. In other words, plastic soil will deform under a stress or pressure without fracturing. Because plasticity is a characteristic imparted as a function of cohesive forces, not all soil is capable of exhibiting plastic behavior.

Granular coarse-textured soils such as sands offer little to no plasticity. The degree of plasticity that a given soil exhibits is a function of the water content of the soil. The lower limit of plasticity (drier) is the point at which soil behaves more as a solid. The upper limit of plasticity (wetter) is the point at which soil behaves more as a liquid. The lower limit is termed "plastic limit" while the upper limit is termed the "liquid limit." The difference between the two limits is called the plasticity index. In general, liquid and plastic limits increase with clay and organic matter content.

Another consistence limit of practical use is the shrinkage limit. The shrinkage limit is a limit within the solid phase at which a soil exhibits a moist friable consistency from the hard consistency of a dry soil. Table 1 shows some examples of values that can be exhibited for various soils that exhibit plasticity.

Strength

Strength is a soil property imparted by cohesive forces between particles and frictional resistance met by particles that are forced to slide over one another to ride out of interlocked positions. Strength characteristics tend to increase with increasing bulk density (compaction) and decreasing water content. For example, in a given soil, strength is greater when the soil is in a dry compacted state than when it is loose and moist. Soils in a liquid consistence state show little or no strength properties.

Resiliency (elasticity) is relatively limited in soils and is not generally a strength property of concern. Strength properties of soils concern the stresses that can be applied to a soil that cause permanent deformations until a threshold is reached whereby the soil fails by fracture or by plastic flow.

Soil strength is commonly evaluated as direct shear, torsional shear, triaxial (confined) compression resistance, unconfined compression resistance, rupture, impact resistance and penetration resistance. Although each of these types of soil strength parameters are measured and evaluated differently, each is basically an evaluation of the soil strength characteristics of cohesion and internal friction. A basic equation for expressing soil strength empirically is given by: $S=C+(N \times \tan F)$, where S is soil strength (shear) at the point of failure, C is cohesion, N is the normal or downward passive pressure, and tanF is the coefficient of internal friction. The terms S, C and N have units of force per unit area while F is called the friction angle. The relationship of each of these terms is shown graphically in Fig. 1.

The points determined can be used to establish a line with the angle formed by the slope of the line being the friction angle. With cohesionless sand, the strength term is defined proportionally with the normal load with the intercept of the graph at the axis.

Typically, C values of soils can vary from 0 in sands up to 30 KPa in clays. Angle F can vary from 0 degrees in saturated clays up to 45 degrees in densely packed angular sands.

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